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RESEARCH ARTICLE

The effects of usage of sequential instructional strategies on students' problem-solving ability in selected chemistry concepts.

Gongden ephraim joel Ph.D and delmang tabitha kamji.

Department of science and technology, education, University of jos, p. M. B 2084, jos – plateau state, Nigeria.

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*Corresponding Author

Gongden ephraim joel
Ph.D.

Abstract

The objective of this study was to determine the effects of sequential use of teaching strategies on chemistry students' problem solving ability in tasks involving mole and electrolysis. It sought to find out whether the time of usage of each of three strategies during a lesson matters. The three strategies were: lecture, analogy and discussion method. The design was pretest-posttest experimental design. Sixty senior secondary two chemistry students were randomly selected from three schools, pretested and grouped into three. The first group was taught the mole concept and electrolysis in the sequence: lecture method, analogy and discussion. The second: analogy, discussion and lecture while the third group: discussion, lecture and analogy. The effectiveness of the different sequence of presentation was measured using chemistry problem solving test (CPST). Data obtained were analyzed using one way ANOVA. Results obtained showed that there was no significant difference in the pre-test means scores of the groups. However, there was a significant difference in the post-test mean scores of the three groups. The students in group one who were taught with lecture, analogy and discussion in that sequence, performed better than group two who also performed better than group three. The sequence of presentation affected their problem solving ability. The order in which the three instructional strategies were used during teaching was important. The study recommends the use of student-centered strategies in close succession to one another without interruption when teaching students problem solving in mole and electrolysis.

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Introduction:-

The ability of students to solve problems irrespective of their sex is instrumental to successful chemistry learning. Problem-solving has been defined variously to mean many things to many people (Danjuma, 2005). Blosser (1998) pointed out that it includes attitude or a predisposition toward inquiry as well as the actual processes by which individuals attempt to gain knowledge. Similarly, Olajengbesi and Aluko (2000) defined it as a cognitive learning strategy which has to do with the bridging of gap between problem state and solution state. Generally, problem solving can be said to be a form of discovery learning that bridges the gap between students' existing knowledge and the solution to a problem. This will involve accepting the challenge to get involved and to strive towards a solution.

Problem solving involves finding a solution path that leads from the initial problem state to the goal state in which case it is an information-processing framework (Heyworth, 1989). It can therefore be said to be a goal-directed sequence of cognitive operations which a person decides to use leading from instruction in a question to the answer. Most instructions in science aim at achieving goals among which are the ability to solve problems. There is therefore the need to help students develop problem solving skills to enable them acquire a deeper understanding of a course material that can help them apply it to other disciplines and life situations in general. Problem solving has been an

aspect of chemistry teaching and learning that has attracted the attention of many chemistry educators. This arose from the fact that problem solving is key in chemistry and most difficulties that students encounter involve problem-solving (Mason, Shell and Crawley, 1997).

The learning of scientific concepts in the Nigeria Senior Secondary School is generally regarded as being difficult for most of the students (Oloyede., 1998). This is particularly true of chemical concepts which are inherently formal in context. WAEC (1995-2012) chief examiners' reports have over the years pointed out the fact that chemistry students often encountered difficulty solving chemical problem tasks. In the 2005 report, students' inability to calculate mole, mole ratio and the use of wrong expressions in solving problems were reported. Commenting on questions involving problem solving in electrolysis, the chief examiners' reports for 1999 and 2003 said that students showed shallow understanding of the concept of electrolysis along with chemical equilibrium and rates of reactions. The general inability of students to tackle most of the numerical (problem solving) questions was also reported. This poor problem solving ability has led to the poor performance of chemistry students in the WAEC examinations (Jimoh, 2004; Njoku, 2007) with a general decline in performance from 2007 to 2009. The poor problem solving ability pointed to a likely deficiency in method of instruction.

Various reasons have been given for the poor performances of chemistry students in problem solving tasks. These include their poor mathematical backgrounds, abstract nature of the concepts, misconceptions, etc. Gabel (2003) said that the main reason why students are unable to solve problems in science education lies with the method of instruction. Teachers do not present the concepts in a variety of contexts for students to understand but in verbal and formal ways. This view and other reports suggest the need to find out which instructional strategies can best influence students' problem solving performance in chemistry.

Teaching methods can best be described as the types of principles and strategies used for instruction (Gatto, 2000). There are many types of teaching methods depending on the skill or information the teacher wants to convey to his students. Among the conventional methods that have been used over the decades are demonstration, field trip, discovery questioning, memorization, discussion, inquiry and the lecture method which still dominates in most classes (Arul, 2012). One major deficiency that has been noted however is that most conventional methods do not allow for students' active participation in learning the material. Most of them are teacher centered strategies. Science educators had to look inward. Research works over the years have led to the development of some student – centered (metacognitive) strategies which have been proposed for use. These instructional strategies include wait time, analogy, concept mapping, mathematical problem solving, collaborative learning, inquiry, discussion, science/technology/society, amongst others (Gabel, 2003b). Most of those who teach chemistry grew up learning chemistry through the lecture method (Timberlake, 2009). She observed that this lecture system is still the preferred teaching styles used by over 89% of science teachers with many finding it a comfortable instructional strategy.

Gabel (2003a) observed that most students often fail to understand the concepts on which problems are based as a result of the way they are taught - being presented in verbal and formal ways that lead to rote learning and memorization. This shows that students' successes in the classroom depend largely on effective teaching methods. For an effective teaching to occur, a good method must be adopted. However, no one strategy is sufficient on its own. A variety of strategies and methods ensure that all students have equal opportunities to learn. There is therefore no one method that is perfect and can be used without the application of another in the course of teaching. One of the most important issues in the application of learning theory is sequencing of instruction. Early reports of (Glynn and DiVesta (1977); Lorch and Lorch (1985) and Van Patten, Chao and Reigeluth (1986) indicate that the order and organization of learning activities affects the way information is processed and retained. Sequencing therefore strongly influence what is learned, how fast performance increases, and sometimes whether learning takes place. Instructional sequencing is the ordering of learning activities (in this case, instructional strategy) within a series of lessons and/or a single lesson. Sequencing strategies depend upon the learning outcome(s) one is attempting to accomplish. One must also take into consideration the amount of time and instructional resources one plans to devote towards the outcome. By properly addressing these sequencing issues, one can maximize the learning opportunities of students.

Statement of the Problem:-

Quite a number of studies have reported that the performance of chemistry students at the secondary and tertiary levels has been poor and deplorable over the years. Amongst them are such as Jimoh (2004) and Njoku (2007). Other studies such as Crippen, Brooks and Courtright (2000); Wagner, 2001; and Danjuma (2005) have reported the

poor performance of chemistry students in problem – solving tasks. Despite these studies and their recommendations, the performance of secondary school students in chemistry examinations in Nigeria is not impressive as reports have indicated. Among the reasons given for this trend is students' poor problem solving ability in chemistry concepts such as the mole, stoichiometry, chemical equilibrium, thermodynamics and electrolysis. Furio, Azcona and Guisasola (2000) and Ezenwa (2005) observed that the abstract and confusing nature of most of the concepts and their applications to problem-solving makes learning the concept difficult for students and teaching the concept challenging to teachers.

The poor problem solving ability of students points to a likely deficiency in method of instruction, a conclusion also drawn by Gabel (2003a). Teachers are expected to use more than one method and to combine such methods to successfully teach their students. The neglect of students' centered learning strategies has been identified as one of the major reasons for students' poor performance in secondary science education Ezenwa (2005). Various studies have been carried out on the effectiveness of student-centered strategies. Some of the conventional methods have also proved effective in many aspects of learning. Arul (2012) proposed that the use of a variety of strategies and methods will ensure that all students have equal opportunities to learn. However, the effects of such a combination of methods on students' problem solving ability in mole and electrolysis have not been documented. If a teacher plans to use a combination of these strategies, will the order matter? What will be the most effective sequence of use of such methods? What will be the effect of sequencing the instructional strategies on students' problem solving ability in tasks involving electrolysis and mole?

Objective of the Study:-

The purpose of the study was to find out how the sequence of use of three instructional strategies affect students' problem solving ability in tasks involving mole and electrolysis. The three methods are: lecture, discussion, and analogy. Specifically, the study sought to find which sequence is more effective in teaching students problem solving in the selected concepts.

Research Question:-

1. What is the difference in pretest mean scores of students in the three groups in a chemistry problem solving test?
2. Are there any differences in the posttest mean scores of the students in the three groups in a chemistry problem solving test?
3. Which sequence produces the greatest effects (results) in students' in the three groups in a chemistry problem solving test involving electrolysis and the mole

Research Hypotheses:-

1. There is no significant difference in the pretest means scores of the students in the three groups in a chemical problem solving test involving mole and electrolysis.
2. There is no significant difference in the posttest means scores of the students in the three groups in a chemical problem solving test involving mole and electrolysis.

Materials and methods:-

The study was an experimental (pretest-posttest) study. It involved three groups of senior secondary two chemistry students drawn from three schools in Plateau central senatorial district.

Twenty students from each of the three schools were randomly selected to give the sample of the study (sixty students). The three schools were randomly grouped into three. Characteristics common to the sample include the use of the same curriculum (and syllabus), their being prepared for the same external examinations, their socio-economic background being similar to one another, etc. A pretest was given to each group in order to determine any differences that existed among the groups. The instrument for data collection was the chemistry problem solving test (CPST) developed by the researchers and validated appropriately. The coefficient of reliability achieved through inter-scoring method was found to be 0.90. The three groups of students were taught the two concepts in different sequence as follows:

Group One, A: Lecture - Analogy – Discussion

Group Two, B: Analogy – Discussion – Lecture

Group Three, C: Discussion – Lecture - Analogy

In the lecture method, the lesson was presented orally on the topics without using any analogy or raising any point that requires discussion. Students listened as the teacher talked and gained whatever they were able to get from the teacher. In discussion, the teacher sets the ball rolling by introducing the topic. He then asked some key questions and allowed the students to discuss in small groups of five each. In the use of analogies, the teacher used familiar stories, events and practices in community to explain the concepts being taught. He linked the familiar analog to the target domain. With this one, he was able to make connections between scientific concepts and students' life-world experiences and helped the students visualize, abstract ideas. Different analogies are used to teach the mole and electrolysis.

After two weeks, a posttest was given. The scores were analyzed to establish whether the use of different sequences to teach the mole and electrolysis was important for solving problems in tasks involving the selected concepts. The effect was determined by a written test, the CPST which was earlier administered during the posttest.

The analysis of the data was statistically done using one way analysis of variance (ANOVA) and the result presented and discussed.

Results:-

Table 1a:- One way ANOVA for Mean Pretest Scores Difference across the Groups (Hypothesis One)

Group	N	Mean score	S.D	Min.	Max.	S. E
Group A	20	32.65	4.782	24	40	1.069
Group B	20	32.85	6.115	24	43	1.367
Group C	20	32.60	6.167	20	42	1.379
Total	60	32.70	5.627	20	43	0.727

Table 1b:- Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
0.918	2	57	0.405

Table 1c:- ANOVA (Pretest Scores)

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	0.7	2	0.35	0.011	0.989
Within Groups	1867.9	57	32.77		
Total	1868.6	59			

From the results, the p -value of 0.989 is more than 0.05. This means that there was not a statistically significant main effect amongst the groups. The null hypothesis one not rejected. Therefore, there was not a statistically significant difference in the pretest means scores of the students in the three groups in a chemical problem solving test involving mole and electrolysis. The implication is that the three groups of students were equivalent (similar), hence the null hypothesis one is upheld.

Table 2a:- Oneway ANOVA for mean posttest test scores of difference across the groups (Hypothesis two) - Descriptives (Posttest score)

Group	N	Mean	Stand Dev	Std Error	95% Confidence Interval for Mean			
					Lower Bound	Upper Bound	Min	Max
A	20	64.2	7.23733	1.618	60.8128	67.5872	50	79
B	20	59.5	6.58947	1.473	56.416	62.584	50	71
C	20	56.25	6.69544	1.497	53.1164	59.3836	49	70
Total	60	59.9833	7.49122	0.967	58.0481	61.9185	49	79

Table 2b:- Test of Homogeneity of Variances (Posttest Scores)

Levene Statistic	df1	df2	Sig.
0.101	2	57	0.904

Analysis of the mean scores for within and between groups in Table 2c yielded p -values of 0.002, $p < 0.05$. The analysis showed that there was a significant difference between the posttest means scores of the students in the three

groups. The null hypothesis two was rejected and the alternate accepted. Therefore, there was significant difference in the posttest means scores of the students in the three groups in a chemical problem solving test involving mole and electrolysis.

The implication is that the effects of sequence of instructional strategies on students' problem solving ability in selected chemistry concepts for the posttest scores in the three groups are not similar. Hence the null hypothesis two is rejected.

Table 2c:- ANOVA

Squares	Sum of	df	Mean Square	F	Sig.
Between Groups	639.03	2	319.517	6.816	0.002
Within Groups	2672	57	46.876		
Total	3311	59			

Multiple comparisons of the posttest scores in table 2d gave the following mean differences values: Group A – Group B (4.70); Group A – Group C (7.95) and Group B – Group C (3.25). The source of difference is significant among the groups at 0.05 level except for the Group B – Group C pair where there is no significant difference, $p = 0.139$ with $p > 0.05$. Group A sequence (lecture – analogy – discussion) showed itself as an effective sequence than the other two.

Table 2d:- Post Hoc Multiple Comparisons of Posttest Scores (Dependent Variable: LSD)

Group (i)	Group (j)	Mean diff. (i-j)	Standard error	Sig.
A	Group B	4.70000	2.16509	0.034
	Group C	7.95000	2.16509	0.001
B	Group A	-4.70000	2.16509	0.034
	Group C	3.25	2.16509	0.139
C	Group A	-7.95000	2.16509	0.001
	Group B	-3.25	2.16509	0.139
The mean difference is significant at the 0.05 level				

According to the results presented, the problem solving ability of students in mole and electrolysis in group A (lecture – analogy – discussion) was higher than that of group B (analogy – discussion - lecture) and group C (discussion – lecture – analogy). The difference was significant at 0.05 level of significance. This means that the sequence lecture – analogy – discussion in group A was more effective than other sequences.

Discussion of results:-

The study showed that there was no significant difference in the pretest means scores of students in the three groups (sequences). This is to be expected as the student sample was drawn from a population that share common characteristics. Moreover, the random selection and assignment of the students into the different groups ensures equivalence of the groups.

Analysis of the posttest scores however showed that there was a statistically significant difference in the posttest means scores of the students in the three groups in a CPST involving mole and electrolysis. Specifically, the sequence used for group A, lecture – analogy – discussion, proved more effective than the sequence B: analogy – discussion – lecture, which was better than C, discussion – lecture – analogy. The sequence used in group A was found to be responsible for the significant difference in the posttest mean scores. A look at the sequence reveals that students developed better understanding and better problem solving skills if the student-centered strategies are presented one after the other to help students construct and build their knowledge based on existing knowledge as in group A. A typical lesson that opens with lecture to introduce the subject after which students are engaged through the use of relevant analogies followed by discussion, enhance the building of better understanding of concepts hence effective problem solving.

Generally, the results showed that the order in which instructional strategies are used in a classroom is important in teaching students problem solving in mole and electrolysis. The result which is in agreement with Arul (2012) who earlier recommended the use of more than one instructional strategy in a classroom during teaching, disagreed with that of Mukherjee, Fogarty and Geeland (2011). In a study on the order of instruction effects on senior chemistry students, Mukherjee, et al, (2011) found out that teaching sequence is not important in terms of students' conceptual

learning gains. It also disagreed with Veselinovska (2001), who found that retention level of students in biology was higher when the sequence begins with demonstration or experimentation than lecture. The result was also at variance with that of Deblina (2012) who found out that organic chemistry students' learning, performance and motivation were significantly better among students who took laboratory and lecture courses simultaneously rather than separately. Even though the study disagreed with these previous findings, it must be noted that the subject and objective of study differed from those previous studies. It can be concluded that in regards to problem solving ability in mole and electrolysis, the teaching sequence is important.

Analogies and discussion are both student-centered and are powerful tools for facilitating an individual's construction of knowledge. Both provide students opportunity to interact and build on existing knowledge (James, Scharmann and Lawrence, 2007). As a result, whatever is learned tends to last longer than usual. In using the lecture method, the teacher talks most of the times, leading to, fleeting coverage of numerous topics but without understanding. Most students often fail to understand the concepts on which problems are based as a result of the way they are taught being presented in verbal and formal ways that lead to rote learning and memorization (Gabel, 2003a). The result showed that when the lecture method is used after two student-centered strategies as in B, students' conception and problem solving ability is retarded. Probably the lecture method used at the end introduces some confusion or misconception. Similarly, when the lecture strategy interjects two student-centered strategies as in C, it affects students' mastery of the concepts and hence their problem-solving ability in the selected concepts.

Conclusion:-

Learning is a process which involves formulating, investigating, reasoning and using appropriate strategies to solve problems. The study here shows that it is necessary for teachers to use different strategies that will involve the students participating as well as the teacher. However, the sequence of the presentation of such strategies matters. Sequencing is one of the most important instructional planning issues that science educators need to address. In order to be effective, lessons and/or learning activities must be sequenced in such a way as to take into consideration students' prior knowledge, skill, and/or experience. The study shows clearly that there is an advantage in the use of more than one teaching method in a class and for a topic. A variety of strategies and methods ensure that all students have equal opportunities to learn. There is therefore no one method that is perfect and can be used without the application of another in the course of teaching. It however shows that the sequence of using such methods matter very much. In the light of this, chemistry teachers should increase their knowledge of the various teaching strategies especially those that are student centered and use the same in teaching problem solving. In using more than two strategies, the teachers should be careful not to obstruct students' active participation in the student-centered strategies with lecture. Lecture method should be used to introduce the topic only where possible.

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